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# Characterization of MWC (Municipal Waste Combustion) Ashes and Leachates from MSW (Municipal Solid Waste) Landfills Monofills, and Co-Disposal Sites. Volume 3

NUS Corp., Pittsburgh, PA

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# Characterization of MWC Ashes and Leachates from MSW Landfills, Monofills, and Co-Disposal Sites

## Volume III of VII
## Addendum to Characterization of Municipal Landfill Leachates —A Literature Review

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FINAL

# ADDENDUM TO CHARACTERIZATION OF MUNICIPAL LANDFILL LEACHATES - A LITERATURE REVIEW

VOLUME III OF VII

Prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY
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## ACRONYMS AND DEFINITIONS

| | |
|---|---|
| BNA | Base-neutral and Acid Extractables |
| BOD | Biological Oxygen Demand |
| CAS | Chemical Abstract Service |
| CB | Chlorobiphenyl |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| COD | Chemical Oxygen Demand |
| Codisposal | Disposal together of municipal solid wastes and municipal solid waste combustion ashes |
| CP | Chlorinated Phenols |
| DWE | Deionized Water Extraction Test Method |
| EP | Extraction Procedure |
| EPA | U.S. Environmental Protection Agency |
| ESP | Electrostatic Precipitator |
| HSWA | Hazardous and Solid Waste Amendments |
| HWC | Hazardous Waste Combustion |
| LF | Landfill |
| MCL | Maximum Contaminant Level |
| Monofill | A landfill that contains only solid waste combustion ashes and residues |
| MSW | Municipal Solid Waste |
| MW | Monitoring Well |
| MWC | Municipal Waste Combustion |
| MWEP | Monofilled Waste Extraction Procedure, also known as SW-924 |
| ND | Not Detected |
| NPDES | National Pollutant Discharge Elimination System |
| PAHs | Polynuclear Aromatic Hydrocarbons |
| PCBs | Polychlorinated Biphenyls |

**ACRONYMS AND DEFINITIONS**
**PAGE TWO**

| | |
|---|---|
| PCDDs | Polychlorinated dibenzo-p-dioxins |
| PCDFs | Polychlorinated dibenzofurans |
| POTW | Publically Owned Treatment Works |
| RCRA | Resource Conservation and Recovery Act |
| RDF | Refuse Derived Fuel |
| RPD | Relative Percent Difference |
| SS | Suspended Solids |
| SW-924 | Deionized Water Extraction Test Method |
| TCLP | Toxic Characteristics Leaching Procedure Test Method |
| TDS | Total Dissolved Solids |
| TEF | Toxic Equivalency Factors |
| TNK | Total Nitrogen Kjeldahl |
| TOC | Total Organic Carbon |
| TSCA | Toxic Substances Control Act |

## 1.0 INTRODUCTION

The purpose of this report is to summarize the findings of literature focused on the assessment of leachate production at municipal solid waste landfills. This is undertaken in support of the USEPA study of the RCRA Subtitle D Program. The EPA is mandated to assess the potential impacts of solid waste municipal landfills on human health and the environment and to make recommendations concerning possible changes to the Subtitle D Program. This study is one of a series of investigations designed by EPA to aid EPA in this task.

This report summarizes information found on factors influencing both the quantity and quality of leachates generated at Subtitle D municipal landfills and presents data generated on the composition of real leachates and leachates formulated under test conditions (extracts).

The NUS report Determination of Municipal Landfill Leachate Characteristics was the first literature review report issued for this purpose. It reviewed only the following three documents.

- McGinley, P. M., and P. Kmet. Formation, Characteristics, Treatment, and Disposal of Leachate from Municipal Solid Waste Landfills. Wisconsin Department of Natural Resources Special Report, August 1, 1984.

- Sobotka & Co., Inc. Case history data compiled and reported in a July 1986 report to the U.S. EPA's Economic Analysis Branch of the Office of Solid Waste.

- Brown, K. W., and K. C. Donnelly. The Occurrence and Concentration of Organic Chemicals in Hazardous and Municipal Waste Landfill Leachate. Texas A&M University, Soil and Crop Sciences Department, College Station, Texas.

This report summarizes additional reports and published papers on the subject. This literature was searched by EPA and NUS. The list of references reviewed in the course of this study is provided in the Reference section (6.0).

## 2.0 FACTORS AFFECTING LEACHATE VOLUME

Leachate volume generation is dependent on numerous factors that generally can be grouped into the following four categories:

1. Availability of water
2. Landfill surface conditions
3. Refuse conditions
4. Underlying soil conditions

Some of these factors are directly related to the waste and to the geographic and climatic locations of the landfill whereas others can be controlled by landfill operators and designers.

Factors affecting water availability include precipitation, surface run-on, groundwater intrusion, irrigation, refuse decomposition, and co-disposal of liquid waste or sludge with refuse. Of these, precipitation in the form of both rain and snow should be the largest contributor of liquid to the landfill.

Water reaching the landfill surface may either evaporate or transpire, run off, or infiltrate the soil surface, depending on landfill surface conditions. These conditions include topography, temperature, humidity, wind speed, vegetation, and cover material (type, dimensions, water content, compaction, permeability, etc.).

After the surface cover material has been fully saturated, refuse retention and transmission characteristics determine the rate of percolation of leachate through the refuse. Theoretically, water does not move through a compacted refuse cell until the field capacity of the waste has been exceeded. Realistically though, because of the heterogeneous nature of most wastes, the channeling of some water through the waste does occur prior to the attainment of field capacity. Once field capacity has been reached, any additional moisture will cause leachate movement.

Ultimately, underlying soil conditions can modify the rate and amount of leachate generation. Soils underlying and surrounding the refuse cell, which have lower permeabilities than the cover soil and refuse, can determine the rate of infiltration

and percolation and thus the volume of leachate generated. Where underlying layers are unsaturated, the infiltration rate is determined by the permeability of the upper layers. Where underlying layers are saturated, the layer with least permeability will control infiltration. When fine-grained underlying soils control infiltration and percolation, the upper layers will become saturated or the water will flow laterally.

Landfill design, management or operating procedures can influence factors such as water availability, surface conditions, and refuse conditions and thus influence the volume of leachate generated. These procedures include handling of cover material, watering prior to compaction, variation in compaction and cell construction, and variation in waste composition.

## 3.0 FACTORS AFFECTING LEACHATE COMPOSITION

Leachate composition, like volume generation, is a function of several variables that are both inherent in the refuse mass and landfill location, and created by landfill operators and designers. These factors include, but are not limited to, refuse composition and processing, landfill age or stage of maturation, rate of water application, and the depth of the leached bed (or thickness of waste layers).

### 3.1 Refuse Composition

Wastes reaching municipal solid waste landfills can be grouped into five categories:

- Residential
- Agricultural
- Commercial
- Municipal
- Industrial

Residential and commercial wastes are composed primarily of rubbish (paper, plastics and glass), food wastes, and ashes from waste incineration. Agricultural waste includes, in addition to wastes similar to residential wastes, organic materials from crops and animals. Industrial wastes contain materials characteristic of the industry from which they were generated and may include sludges, ashes, and industrial residues. Presently, municipal landfills are not permitted to accept hazardous industrial wastes except those generated from small-quantity generators. Municipal wastes consist of a diverse list of wastes. The relative composition of municipal solid waste, as determined by several investigators, is presented in Table 3-1 (Pohland and Harper, 1984).

The codisposal of industrial sludges, ashes, and residues with residential, commercial, municipal, and other solid wastes can contribute toxic compounds, both organic and inorganic, to leachates and subsequently to groundwater. The small generator exclusion rule under RCRA has allowed the disposal of small quantities of these hazardous materials in sanitary landfills. Additionally, small quantities of hazardous constituents are disposed from households and businesses

**TABLE 3-1**

**RANGE OF COMPOSITION OF MUNICIPAL SOLID WASTE***

| Component | Average | Average | Average | Range | Average | Range | Average | Range | Typical |
|---|---|---|---|---|---|---|---|---|---|
| Food Wastes | 12 | <25.1 | 25.0 | 8.8-12.8 | 10.7 | 4-9 | 7 | 6-26 | 15 |
| Garden Wastes | | | 0 | 5.8-17.0 | 10.4 | 1-10 | 5 | 0-20 | 12 |
| Paper | 39 | 44.5 | 50.0 | >35.2-25.3 | >40.6 | 45-57 | 50 | 25-45 | 40 |
| Cardboard | 7 | | | | | | | 3-15 | 4 |
| Plastics | | >22 | >3.0 | >4.2-5.2 | >4.5 | | | 2-8 | 3 |
| Rubber | 2 | | | | | 4-9 | 6 | 0-2 | 1 |
| Leather | | | | | | | | 0-2 | 1 |
| Textiles | 3 | 1.1 | 5.0 | 1.1-2.5 | 1.7 | 2-5 | 3 | 0-4 | 2 |
| Plastic File | 2 | | | | | | | | |
| Wood | 7 | | 1.0 | 0.4-1.3 | 1.0 | 1-2 | 1 | 1-4 | 2 |
| Glass | 10 | 11.3 | 7.0 | 9.1-12.4 | 10.9 | 9-17 | 12 | 4-16 | 8 |
| Metallics | 8 | 8.7 | 4.0 | 8.0-8.6 | 9.0 | 6-15 | 10 | | |
| Tin Cans | | | | | | | | 2-8 | 6 |
| Non-Ferous Metals | | | | | | | | 0-1 | 1 |
| Ferrous Metals | | | | | | | | 1-4 | 2 |
| Dirt , Ashes, Brick. etc. | 10 | 7.1 | 5.0 | 1.0-3.6 | 2.3 | 3-15 | 7 | 0-10 | 4 |
| Moisture | | | | | | 21-35 | 27 | 15-40 | 20 |

*Percent by weight, wet weight basis
Source: Pohland and Harper, 1984

and reach the sanitary landfill as residential, commercial, agricultural, or municipal wastes.

Several municipal solid waste landfills throughout the country serve as co-disposal sites where, along with refuse, ash from municipal waste incinerators is disposed. Several studies have been conducted on the characteristics of municipal waste combustion (MWC) leachates and codisposal leachates. Results for these studies are discussed in Section 4.0 of this report.

## 3.2 Landfill Age or Degree of Stabilization

According to Pohland and Harper, 1984, the coupling of landfill age with leachate production has been one of the most elusive challenges for landfill operators, designers and regulators. Most municipal waste landfills proceed through a series of predictable phases whose significance and longevity are determined by the previously mentioned inherent and controlled climatological and operational factors.

A municipal landfill exists throughout much of its active life as an anaerobic microbial unit that experiences an initial lag period that lasts until sufficient moisture has accumulated to sustain a viable microbial community. Thereafter, further manifestations of waste conversion and stabilization occur in more or less distinct phases. These phases are described by Pohland and Harper (1984) as follows.

**Phase I: Initial Adjustment**

- Initial waste placement and preliminary moisture accumulation.
- Initial subsidence and closure of each landfill area.
- Changes in environmental parameters first detected to reflect the onset of stabilization processes, which are trending in a logical fashion.

**Phase II: Transition**

- Field capacity is exceeded and leachate is formed.
- A transition from initial aerobic to anaerobic microbial stabilization occurs.
- The primary electron acceptor shifts from oxygen to nitrates and sulfates with the displacement of oxygen by carbon dioxide in the gas.
- A trend toward reducing conditions is established.
- Measurable intermediates such as the volatile organic fatty acids first appear in the leachate.

**Phase III: Acid Formulation**

- Intermediary volatile organic fatty acids become predominant with the continuing hydrolysis and fermentation of waste and leachate constituents.
- A precipitous decrease in pH occurs with a concomitant mobilization and possible complexation of metal species.
- Nutrients such as nitrogen and phosphorus are released and utilized in support of the growth of biomass commensurate with the prevailing substrate conversion rates.
- Hydrogen may be detected and affect the nature and type of intermediary products being formed.

**Phase IV: Methane Fermentation**

- Intermediary products appearing during the acid formation phase are converted to methane and excess carbon dioxide.
- The pH returns from a buffer level controlled by the volatile organic fatty acids to one characteristic of the bicarbonate buffering system.
- Oxidation-reduction potentials are at their lowest values.
- Nutrients continue to be consumed.
- Complexation and precipitation of metal species proceed.
- Leachate organic strength is dramatically decreased in correspondence with increases in gas production.

**Phase V: Final Maturation**

- Relative dormancy following active biological stabilization of the readily available organic constituents in the waste and leachate.
- Nutrients may become limiting.
- Measurable gas production all but ceases.
- Natural environmental conditions become reinstated.
- Oxygen and oxidized species may slowly reappear with a corresponding increase in oxidation-reduction potential.
- More microbially-resistant organic materials may be slowly converted with the possible production of humic-like substances capable of complexing with and re-mobilizing heavy metals.

Table 3-2 illustrates the variation in leachate composition caused by the progression of the landfill through the stabilization phases.

The rate of progress through these phases is dependent on the physical, chemical, and microbiological conditions developed within each landfill cell. For example, acidic conditions established during acid formation may preclude methane fermentation; high compaction may restrict the movement of moisture and nutrients through the waste; and microbial inhibition may be induced by the presence of toxic substances. This last example means that in-situ stabilization may occur at reduced rates as the leachate becomes more concentrated and the extended stabilization period increases the opportunity for leachate migration from the landfill. In addition, this leachate is likely to be carrying some of the microbe-inhibiting toxic constituents with it.

### 3.3 Rate of Water Application and Refuse Depth

As mentioned earlier, the rate of water application and refuse depth have an effect on the leachate composition. Once the soil has been saturated with moisture, leaching closely follows the rate of moisture input. Because of this input-output leaching pattern , it is found that higher rates of water application to a landfill will produce a more dilute leachate than lower rates of water applications.

A comparison of refuse test cells with and without continuous flow-through of water showed that continuous flushing brought about a marked trend toward reduced levels of dissolved materials. This proved true for both inorganic and organic solutes, and demonstrates the important effect of dilution on leachate quality.

Refuse depth works in conjunction with water application rates in affecting the composition of the leachate. Water travels from the top of the refuse mass, moving from one void space to the next until it reaches the bottom of the fill. The percolating water will accumulate contaminants until the solubility limit of the leaching solution is attained. Thus, for a deeper landfill, the probability of the leachate reaching its solubility limit is greater than for a shallower landfill, because of greater contact time between refuse and percolate. However, much depends on the rate at which the water percolates through the landfill. Higher infiltration

**TABLE 3-2**

**LANDFILL LEACHATE CONCENTRATION RANGES AND THEIR RELATIVE SIGNIFICANCE TO THE DEGREE OF LANDFILL STABILIZATION**

| Leachate Constituent | Phase of Biological Stabilization | | | | Overall Range |
|---|---|---|---|---|---|
| | Transition Phase | Acid Formation Phase | Methane Fermentation Phase | Final Maturation Phase | |
| Biochemical Oxygen Demand ($BOD_5$) mg/l (ppm) | 100-10,900 Influence of dilution and aerobic solubilization of waste organics | 1,000-57,700 Accumulation of biodegradable organic acids due to methanogenic lag | 600-3,400 Conversion of biodegradable organics to gaseous end products ($CH_4$ and $CO_2$) | 4-120 Influence of high molecular weight organic residuals (humics, fulvics) | 4-57,7000 |
| Chemical Oxygen Demand (COD) mg/l (ppm) | 480-18,000 Trending in a similar fashion to $BOD_5$ | 1,500-71,100 Trending in a similar fashion to $BOD_5$ | 580-9,760 Trending in a similar fashion to $BOD_5$ | 31-900 Higher influence of residual organics than in $BOD_5$ assay | 31-71,100 |
| Total Volatile Acids (TVA), mg/l (ppm) as Acetic Acid | 100-3,000 Beginning to appear as a result of aerobic solubilization | 500-27,700 Increasing rapidly; accumulation due to methanogenic lag | 300-2,230 Conversion of volatile acids to methane; decrease in aqueous carbon | 70-260 Influence of high molecular weight organics | 70-27,700 |
| Total Organic Carbon (TOC), mg/l (ppm) | 100-3,000 Beginning to appear as a result of solubilization | 3,000-18,800 Solubilization of organic polymers to monomers; beta oxidation to volatile acids | 250-4,000 Conversion of fatty acids to acetic acid; fermentation of acetic acid to methane | Essentially absent; methanogenic system undersaturated | 0-18,800 |
| $BOD_5$/COD Ratio | 0.23-0.87 Increasing biodegradability of organics due to solubilization | 0.4-0.8 High biodegradability | 0.17-0.64 Decreasing biodegradability due to methanation | 0.02-0.13 Low degree of biodegradability | 0.02-0.87 |
| COD/TOC Ratio | 4.3-4.8 Low oxidation state of organics | 2.1-3.4 Low to moderate oxidation state of organics | 2.0-3.0 Moderate to high oxidation of organics | 0.4-2.0 | 0.4-4.8 |

**TABLE 3-2**
**LANDFILL LEACHATE CONCENTRATION RANGES AND THEIR RELATIVE SIGNIFICANCE TO THE DEGREE OF LANDFILL STABILIZATION**
**PAGE TWO**

| Leachate Constituent | Phase of Biological Stabilization | | | | Overall Range |
|---|---|---|---|---|---|
| | Transition Phase | Acid Formation Phase | Methane Fermentation Phase | Final Maturation Phase | |
| Total Kjeldahl Nitrogen (TKN), mg/l (ppm) | 180-360 | 14-1,970<br>May be low due to microbial assimilation of nitrogenous compounds | 25-82<br>Low due to microbial assimilation of nitrogenous compounds | 7-490 | 7-1,970 |
| Nitrate Nitrogen ($NO_3$-N), mg/l (ppm) | 0.1-51<br>Increasing due to oxidation of ammonia | 0.05-19<br>Decreasing due to reduction to ammonia or nitrogen gas | Absent<br>Complete conversion to ammonia or nitrogen gas | 0.3-0.6 | 0-51 |
| Ammonia Nitrogen ($NH_3$-N), mg/l (ppm) | 120-225 | 2-1,030<br>Increasing due to nitrate reduction and protein breakdown | 6-430<br>Decreasing due to biological assimilation | | |
| NH3-N/TKN Ratio | 0.1-0.9 | 0-0.98<br>Protein breakdown; biological assimilation | 0.1-0.84 | 0.3-0.97 | 0-0.98 |
| Total Phosphate (PO4-P),mg/l (ppm) | 0.6-1.7 | 0.2-120<br>Biological assimilation and metal complexation | 0.7-14<br>Low due to biological assimilation | 0.2-14 | 0.2-120 |
| Total Alkalinity, mg/l (ppm) as $CaCO_3$ | 200-2,050 | 140-9,650<br>Increasing due to volatile acid formation and bicarbonate dissolution | 760-5,050<br>Decreasing due to volatile acid removal | 200-3,520 | 140-9,650 |

**TABLE 3-2**
**LANDFILL LEACHATE CONCENTRATION RANGES AND THEIR RELATIVE SIGNIFICANCE TO THE DEGREE OF LANDFILL STABILIZATION**
**PAGE THREE**

| Leachate Constituent | Phase of Biological Stabilization | | | | Overall Range |
|---|---|---|---|---|---|
| | Transition Phase | Acid Formation Phase | Methane Fermentation Phase | Final Maturation Phase | |
| Solids (TS), mg/l (ppm) | 2,450-2,960 | 4,120-65,300 Increasing due to solubilization of organics and mobilization of metals | 2,050-6,410 | 1,460-4,640 | 1,460-65,300 |
| pH (pH units) | 6-7 | 4.7-7.7 Low due to volatile acid accumulation | 6.3-6.8 Increasing due to volatile acid removal and bicarbonate dissolution | 7.1-8.8 | 4.7-8.8 |
| Oxidation-Reduction Potential (ORP), mV | + 40 to -40 | + 40 to -240 Decreasing due to the depletion of oxygen | -70 to -240 | -97 to + 163 | -240 to + 163 |
| Copper, mg/l (ppm) | 0.085-0.39 | 0.005-2.2 | 0.03-0.18 Decreasing (complexation) | 0.02-0.56 | 0.005-2.2 |
| Iron, mg/l (ppm) | 68-312 | 90-2,200 | 115-336 Decreasing (complexation) | 4-20 | 4-2,200 |
| Lead, mg/l (ppm) | 0.0001-0.004 | 0.01-1.44 | 0.01-0.1 Decreasing (complexation) | 0.01-0.1 | 0.001-1.44 |
| Magnesium, mg/l (ppm) | 66-96 | 3-1,410 | 81-505 Decreasing (complexation) | 81-190 | 3-1,140 |
| Manganese, mg/l (ppm) | 0.6 | 0.6-41 | 0.6 Decreasing (complexation) | 0.6 | 0.6-41 |

**TABLE 3-2**
**LANDFILL LEACHATE CONCENTRATION RANGES AND THEIR RELATIVE SIGNIFICANCE TO THE DEGREE OF LANDFILL STABILIZATION**
**PAGE FOUR**

| Leachate Constituent | Phase of Biological Stabilization | | | | Overall Range |
|---|---|---|---|---|---|
| | Transition Phase | Acid Formation Phase | Methane Fermentation Phase | Final Maturation Phase | |
| Nickel, mg/l (ppm) | 0.02-1.55 | 0.03-79 | 0.01-1.0 Decreasing (complexation) | 0.07 | 0.02-79 |
| Potassium,mg/l (ppm) | 35-2,300 | 35-2,300 | 35-2,300 | 35-2,300 | 35-2,300 |
| Sodium, mg/l (ppm) | 20-7,600 | | | | 20-7,600 |
| Zinc, mg/l (ppm) | 0.06-21 | 0.65-220 | 0.4-6.0 | 0.4 | 0.06-220 |
| Total Coliform, CFU/100ml | $10^0$-$10^5$ | $10^0$-$10^5$ | Essentially absent | Absent | 0-$10^5$ |
| Fecal Coliform, CFU/100 ml | $10^0$-$10^5$ | $10^0$-$10^5$ | Essentially absent | Absent | 0-$10^5$ |
| Fecal Streptococci, CFU/100ml | $10^0$-$10^6$ | $10^0$-$10^6$ | Essentially absent | Absent | 0-$10^6$ |
| Viruses, PFU/100 ml | - | Essentially absent | Essentially absent | Essentially absent | Absent |
| Conductivity, umhos/cm | 2,450-3,310 | 1,600-17,100 Increasing due to mobilization of metals | 2,900-7,700 Decreasing due to metals complexation with sulfides | 1,400-4,500 | 1,400-17,100 |
| Chloride mg/l (ppm) | 30-5,000 Biologically stable; good indicator of washout | 30-5,000 Stable; good hydraulic tracer | 30-5,000 Stable; good hydraulic tracer | 30-5,000 Stable; good hydraulic tracer | 30-5,000 |
| Sulfate mg/l (ppm) | 10-458 Increasing due to aerobic oxidation | 10-3,240 Increasing initially due to aerobic solubilization then decreasing as anaerobic conditions are established | Absent Complete conversion to sulfides | 5-40 Reappearing due to aerobic oxidation | 0-3,240 |

**TABLE 3-2**
**LANDFILL LEACHATE CONCENTRATION RANGES AND THEIR RELATIVE SIGNIFICANCE TO THE DEGREE OF LANDFILL STABILIZATION**
**PAGE FIVE**

| Leachate Constituent | Phase of Biological Stabilization | | | | Overall Range |
|---|---|---|---|---|---|
| | Transition Phase | Acid Formation Phase | Methane Fermentation Phase | Final Maturation Phase | |
| Sulfide mg/l (ppm) | Essentially absent | 0-618<br>Beginning to appear and increasing due to sulfate reduction under anaerobic conditions | 0.9<br>Low due to heavy metal precipitation | Absent | 0-618 |
| Cadmium, mg/l (ppm) | <0.005-0.01 | <0.005-0.39 | <0.005-0.1<br>Decreasing due to complexation | 0.004 | <0.005-0.39 |
| Calcium, mg/l (ppm) | 190-490 | 70-3,900 | 76-490<br>Decreasing due to complexation and precipitation | 76-254 | 70-3,900 |
| Chromium, mg/l (ppm) | 0.023-0.28 | 0.06-18 | 0.05<br>Decreasing due to complexation, precipitation with sulfides | 0.05 | 0.02-18 |

Source: Pohland & Harper, 1984

*Information taken from best available copy, some values barely legible.

rates increase the percolation rate and reduce the contact time between percolate and refuse. Thus, a more dilute leachate can be expected.

## 4.0 LEACHATE COMPOSITION DATA

As discussed in the previous section, a large number of variables determine the composition of a municipal landfill leachate. Table 4-1 presents literature values demonstrating the concentration ranges for the chemical composition of municipal landfill leachates. From this table and the references indicated, the following observations can be made: leachates are highly variable with respect to constituent concentration; leachates are generally high in total organic carbon and total dissolved solids; and leachates tend to be acidic, though the leachate final pH will be influenced by the buffering capacity of the geologic formation the landfill is placed in.

Table 4-2 demonstrates the wide range in types and concentrations of organic constituents detected in municipal leachate. Most of these compounds do not occur naturally and are a result of the wastes placed in the landfill.

### 4.1 Codisposal of Industrial Wastes and Municipal Solid Wastes

One EPA-sponsored study conducted by Jones et al. (1985) simulated the effects of co-disposal of industrial waste with municipal solid waste (MSW). In this study, MSW leachate was shown to be acidic (pH = 5.3) and to have very high organic and ionic loadings. Early samples in the test exceeded Federal Primary Drinking Water Standards for all constituents with established standards except copper. When untreated industrial wastes, including a glass-electronics etching sludge, a chlorine production brine, and an electroplating waste were added individually to test cells, the leachate pH rose from about 5.3 to 6.3. Also, biological activity was reduced, especially by the glass-electronics etching sludge (COD and BOD values averaged only 28 percent of the values for MSW-only leachates). This illustrates the effect of toxics on biological activity and the stabilization process. Metals in the industrial wastes were generally not readily leached from the test cells. Though the electroplating waste produced significantly increased levels of metals, the increases were small relative to the total metal content in the waste. Soluble salts were readily leached from all of the industrial wastes codisposed with the MSW. Sodium and chlorine concentrations were elevated for all codisposed industrial wastes, especially the chlorine production brine.

**TABLE 4-1**

**RANGE OF CONSTITUENT CONCENTRATIONS IN LEACHATE FROM MUNICIPAL WASTE LANDFILLS**
**(in mg/l (ppm) unless noted)**

| Constituent | Concentration Range |
|---|---|
| COD | 50–90,000 |
| BOD | 5–75,000 |
| Total organic carbon (TOC) | 50–45,000 |
| Total solids (TS) | 1–75,000 |
| TDS | 725–55,000 |
| Total suspended solids (TSS) | 10–45,000 |
| Volatile suspended solids (VSS) | 20–750 |
| Total volatile solids (TVS) | 90–50,000 |
| Fixed Solids (FS) | 800–50,000 |
| Alkalinity (as $CaCO_3$) | 0.1–20,350 |
| Total coliform (CFU/100 ml) | $0–10^5$ |
| Iron | 200–5,500 |
| Zinc | 0.6–220 |
| Sulfate | 25–500 |
| Nickel | 0.2–79 |
| Total volatile acids (TVA) | 70–27,700 |
| Manganese | 0.6–41 |
| Fecal coliform (CFU/1,000 ml) | $0–10^5$ |
| Specific conductance (mhg/cm) | 960–16,300 |
| Ammonium nitrogen ($NH_4$-N) | 0–1.106 |
| Hardness (as $CaCO_3$) | 0.1–36,000 |
| Total phosphorus | 0.1–150 |
| Organic phosphorus | 0.4–100 |
| Nitrate nitrogen | 0.1–45 |
| Phosphate (inorganic) | 0.4–150 |
| Ammonia nitrogen ($NH_3$-N) | 0.1–2,000 |

**TABLE 4-1**
**RANGE OF CONSTITUENT CONCENTRATIONS IN LEACHATE FROM MUNICIPAL WASTE LANDFILLS**
**(in mg/l (ppm) unless noted)**
**PAGE TWO**

| Constituent | Concentration Range |
|---|---|
| Organic nitrogen | 0.1–1,000 |
| Total Kjeldahl nitrogen (TKN) | 7–1,970 |
| Acidity | 2,700–6,000 |
| Turbidity (Jackson units) | 30–450 |
| Chlorine | 30–5,000 |
| pH (dimensionless) | 3.5–8.5 |
| Sodium | 20–7,600 |
| Copper | 0.1–9 |
| Lead | 0.001–1.44 |
| Magnesium | 3–15,600 |
| Potassium | 35–2,300 |
| Cadmium | 0–0.375 |
| Mercury | 0–0.16 |
| Selenium | 0–2.7 |
| Chromium | 0.02–18 |

Source: Sobotka, 1986.

**TABLE 4-2**

**PRELIMINARY DATA ON CONCENTRATIONS OF ORGANIC CONSTITUENTS IN LEACHATE FROM MUNICIPAL WASTE LANDFILLS (units in ppb)[a]**

| Constituent | Minimum | Maximum | Median |
|---|---|---|---|
| Acetone | 140 | 11,000 | 7,500 |
| Benzene | 2 | 410 | 17 |
| Bromomethane | 10 | 170 | 55 |
| 1-Butanol | 50 | 360 | 220 |
| Carbon tetrachloride | 2 | 398 | 10 |
| Chlorobenzene | 2 | 237 | 10 |
| Chloroethane | 5 | 170 | 7.5 |
| Bis(2-chloroethoxy)methane | 2 | 14 | 10 |
| Chloroform | 2 | 1,300 | 10 |
| Chloromethane | 10 | 170 | 55 |
| Delta BHC | 0 | 5 | 0 |
| Dibromomethane | 5 | 25 | 10 |
| 1,4-Dichlorobenzene | 2 | 20 | 7.7 |
| Dichlorodifluoromethane | 10 | 369 | 95 |
| 1,1-Dichloroethane | 2 | 6,300 | 65.5 |
| 1,2-Dichloroethane | 0 | 11,000 | 7.5 |
| Cis 1,2-Dichloroethene | 4 | 190 | 97 |
| Trans 1,2-Dichloroethene | 4 | 1,300 | 10 |
| Dichloromethane | 2 | 3,300 | 230 |
| 1,2-Dichloropropane | 2 | 100 | 10 |
| Diethyl phthalate | 2 | 45 | 31.5 |
| Dimethyl phthalate | 4 | 55 | 15 |
| Di-n-butyl phthalate | 4 | 12 | 10 |
| Endrin | 0 | 1 | 0.1 |
| Ethyl acetate | 5 | 50 | 42 |
| Ethyl benzene | 5 | 580 | 38 |
| Bis(2-ethylhexyl) phthalate | 6 | 110 | 22 |

**TABLE 4-2**
**PRELIMINARY DATA ON CONCENTRATIONS OF ORGANIC CONSTITUENTS IN LEACHATE FROM MUNICIPAL WASTE LANDFILLS (units in ppb)[a]**
**PAGE TWO**

| Constituent | Minimum | Maximum | Median |
|---|---|---|---|
| Isophorene | 10 | 85 | 10 |
| Methyl ethyl ketone | 110 | 28,000 | 8,300 |
| Methyl isobutyl ketone | 10 | 660 | 270 |
| Naphthalene | 4 | 19 | 8 |
| Nitrobenzene | 2 | 40 | 15 |
| 4-Nitrophenol | 17 | 40 | 25 |
| Pentachlorophenol | 3 | 25 | 3 |
| Phenol | 10 | 28,800 | 257 |
| 2-Propanol | 94 | 10,000 | 6,900 |
| 1,1,2,2-Tetrachloroethene | 7 | 210 | 20 |
| Tetrachloroethene | 2 | 100 | 40 |
| Tetrahydrofuran | 5 | 260 | 18 |
| Toluene | 2 | 1,600 | 166 |
| Toxaphene | 0 | 5 | 1 |
| 1,1,1-Trichloroethane | 0 | 2,400 | 10 |
| 1,1,2-Trichloroethane | 2 | 500 | 10 |
| Trichloroethene | 1 | 43 | 3.5 |
| Trichlorofluoromethane | 4 | 100 | 12.5 |
| Vinyl chloride | 0 | 100 | 10 |
| m-Xylene | 21 | 79 | 26 |
| p-Xylene + o-Xylene | 12 | 50 | 18 |

a The table was provided by U.S. EPA, Office of Waste, Economic Analysis Branch. It includes data from 15 municipal landfill case studies performed by OSW[12]; data from landfill leachate sampling studies performed by Wisconsin and Minnesota; and data from NPDES discharge permits for leachates from landfills in New Jersey. These studies provided reliable data, albeit on a relatively small number of facilities.

Source: Sobotka, 1986.

## 4.2 Codisposal of Municipal Waste Combustion Ash and Municipal Solid Wastes

One codisposal practice currently common in the United States and potentially affecting leachate quality is the codisposal of municipal waste combustion (MWC) ash with other municipal solid wastes. A study by GCA Corporation (1986) reports that by the end of 1986, 61 MWC facilities would be in operation and would produce 9,781 tons per day of residue. Eighty-eight percent of these residues would be land disposed, including codisposal with municipal solid wastes. Thus, the composition of these ashes and the effect they may have on the composition of municipal waste leachates must come under scrutiny.

Varying incineration options and fuel composition vary the characteristics of the MWC residues. Tables 4-3 and 4-4 present data on inorganic and organic compositions, respectively, for both MWC fly ash and bottom ash. Table 4-4 shows that polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are present in ash and are more abundant in fly ash than bottom ash. The 2,3,7,8-TCDD dioxin isomer exceeds the EPA standard of 1 part per billion (ppb) for most fly ash data. These data are corroborated by a study done in Japan on municipal incinerator ashes (Wakimoto and Tatsukawa, 1985).

Data presented by GCA Corporation (1986) for MWC residue monofill leachates indicate that lead and chromium values exceed Federal Primary Drinking Water Standards. These results are presented in Table 4-5. Also, EP Toxicity leach testing on various MWC residues resulted in lead and cadmium values above the maximum allowable limits. These data are presented in Table 4-6. These results compare well with results obtained in tests conducted by C.W. Francis (1984) from the Oak Ridge National Laboratory. The author found that a simulated codisposal leachate was more acidic than an ash-only leachate and that a municipal waste leachate extracted metals more aggressively than water. Several of the municipal-waste-leachate ash leachates exceeded Federal Drinking Water Standards, particularly for cadmium and lead during initial leaching.

## TABLE 4-3

### MWC SOLID RESIDUE INORGANIC COMPOSITION (UNITS IN ppm UNLESS NOTED)

| Element | MWC #1, R.C. Fly Ash [1] | Alexandria '[illegible] Fly Ash [2] | Alexandria Scrubber Fly Ash [2][a] | Alexandria Scrubber Fly Ash [2] | Alexandria 1973 Fly Ash [2] | Alexandria 1974 Fly Ash [2] | Sample F-1 Fly Ash [3][b] | Sample F-2 Fly Ash [3][b] | Sample F-3 Fly Ash [3][b] | Sample F-4 Fly Ash [3][b] |
|---|---|---|---|---|---|---|---|---|---|---|
| Na | 14,700 | [illegible] | 16,000 | 14,000 | 16,700 | 14,500 | 26,800 | 20,000 | 15,600 | 13,600 |
| Co | 1.8 | [illegible] | | | | | | | | |
| Mg | 13,000 | 13,000 | 9,700 | 12,000 | 9,500 | 9,600 | 17,100 | 10,300 | 10,300 | 9,800 |
| Ca | 50,000 | [illegible] | 23,000 | 40,000 | 22,000 | 22,000 | 59,000 | 49,000 | 44,000 | 42,000 |
| Sr | 280 | [illegible] | 210 | | 745 | 260 | | | | |
| Ba* | 3,200 | [illegible] | 1,500 | 2,500 | 1,700 | 1,400 | <6,000 | <9,000 | <7,000 | 3,000 |
| Cl | 1,300 | [illegible] | | | | | | | | |
| Br | 35 | 127 | | | | | | | | |
| I | 16 | 23 | | | | | | | | |
| Al | 13,300 | [illegible] | 120,300 | 111,000 | 126,000 | 124,000 | 120,100 | 128,000 | 133,300 | 107,900 |
| Sc | 10.1 | 10.4 | | | | | | | | |
| Ti | 29,000 | 12,000 | <50 | | | | 23,100 | 21,900 | 34,100 | 22,400 |
| V | 140 | 135 | | | | | | | | |
| Cr* | 740 | 1,700 | 1,160 | 1,430 | 1,140 | 730 | <700 | 400 | 300 | 400 |
| Mn | 2,100 | 4,300 | 4,390 | 3,400 | 1,550 | 1,100 | <400 | 700 | 400 | <800 |
| Fe | 35,000 | 52,000 | 35,900 | 46,000 | 34,000 | 33,000 | 28,300 | 30,200 | 20,500 | 21,300 |
| Co | 27 | 35 | 190 | 30 | 100 | 90 | | | | |
| Ni | | 70 | 1,890 | 760 | 1,590 | 160 | <130 | <100 | <100 | <300 |
| Cu | 950 | 960 | 510 | 1,000 | 600 | 445 | 909 | 700 | 670 | 690 |
| Zn | 2,000 | [illegible] | 10,100 | 9,400 | 8,650 | 8,700 | 6,390 | 4,000 | 9,000 | 2,800 |
| As* | 59 | 47 | 77 | 41 | | | | | | |
| Se* | 12 | 3.4 | | | | | | | | |
| Ag* | 220 | 85 | 129 | 106 | 95 | 139 | <100 | <100 | <300 | <100 |
| Cd* | 185 | 42 | 64 | 45 | 56 | 57 | | | | |
| In | 1.0 | 0.71 | | | | | | | | |
| Sn | 2,490 | 1,430 | 1,230 | | 850 | 860 | <400 | 400 | 300 | <500 |
| Sb | 580 | 220 | 340 | 260 | | | | | | |
| La | 31 | 34 | | | | | | | | |
| Ce | 74 | 77 | | | | | | | | |
| Sm | 6.8 | 6.2 | | | | | | | | |
| Eu | 0.92 | 1.03 | | | | | | | | |
| Lu | <1 | 0.22 | | | | | | | | |
| Hf | <0.2 | 1.5 | | | | | | | | |
| Ta | 13.7 | 14 | | | | | | | | |
| Wf | 4.2 | 4.9 | | | | | 300 | <400 | <300 | <300 |
| Re | 35 | 5.1 | | | | | | | | |
| U | 13 | 16 | | | | | | | | |
| Au | 0.61 | 1.3 | | | | | | | | |
| Pb* | 840 | 0.40% | 7,200 | 6,800 | 10,000 | 7,200 | 1,700 | 300 | 2,000 | 2,600 |
| Be | | | <4 | | <4 | <4 | | | | |
| Hg* | | | 0.88 | | | | <300 | <300 | <300 | <300 |
| K | | | 12,200 | | 13,800 | 14,800 | 13,700 | 15,500 | 11,000 | 15,800 |
| Li | | | 34 | | 31 | 34 | | | | |
| Si | | | | | | | 194,500 | 206,000 | 199,500 | 186,400 |
| P | | | | | | | 8,900 | 6,400 | 6,600 | 9,300 |
| C | | | | | | | 52,900 | 8,800 | 2,300 | 116,200 |
| S | | | | | | | 5,700 | 3,800 | 4,700 | 2,800 |
| Cl | | | | | | | <400 | 600 | 700 | <200 |
| Ca | | | | | | | 100 | <100 | <100 | <100 |
| Mg | | | | | | | 200 | <200 | <200 | <200 |
| Fe | | | | | | | | | | |
| Si | | | | | | | | | | |
| B | | | | | | | | | | |

(continued)

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TABLE 4-3

(continued)

| Element | Sample No. 1 Fly Ash (3)[b] | Sample No. 2 Fly Ash (3)[b] | Sample No. 3 Bottom Ash (3)[b] | Bureau of Mines (6) Bottom Ash | Bureau of Mines (6) Fly Ash[c] | Philadelphia, N.W. Bottom Ash (5) | Chicago, No. Fly Ash (7) | Prince Edward Island (8) Bottom Ash | Prince Edward Island (8) Water | Prince Edward Island (8) Groundwater Ash | Sumner, TX (7) Fly Ash | Hastings, [illegible] (7) Fly Ash | Autauga, AL (7) Fly Ash |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Na | 23,100 | 19,400 | 33,300 | 8,200 | 16,900 | | 18,900 | 10,500 | 49,500 | 47,000 | 9,690 | [illegible] | [illegible] |
| Ca | | | | | | | | | | | | | |
| Mg | 10,600 | 10,100 | 6,100 | 12,800 | 9,200 | | 15,000 | 8,733 | 8,950 | 10,667 | 7,700 | [illegible] | [illegible] |
| Ca | 52,000 | 68,500 | 63,500 | 40,000 | 23,000 | | 85,000 | 54,667 | 70,167 | 84,667 | 39,900 | [illegible] | [illegible] |
| Si | | | | | | | 270 | | | | 390 | [illegible] | [illegible] |
| Be* | 4,000 | 2,800 | 7,000 | 1,400 | 1,300 | | 1,600 | 367 | 88 | 78 | 410 | [illegible] | [illegible] |
| Cl | | | | | | | | | | | | | |
| Br | | | | | | | | | | | | | |
| I | | | | | | | | | | | | | |
| Al | 176,000 | 57,400 | 74,700 | 69,000 | 131,000 | 19,100 | 53,000 | 32,667 | 48,033 | 54,000 | 60,000 | [illegible] | [illegible] |
| Sc | | | | | | | | | | | | | |
| Ti | 33,700 | 11,400 | 3,400 | | | | 11,000 | 3,067 | 4,167 | 3,467 | 1,990 | [illegible] | [illegible] |
| V | | | | | | | 36 | 53 | 61 | 71 | 33 | 51 | 19 |
| Cr* | 900 | 400 | 300 | 530 | 1,160 | 50 | 230 | 100 | 100 | 170 | 320 | [illegible] | [illegible] |
| Mn | 700 | <1,000 | <1,000 | 3,100 | 1,500 | | 1,200 | 1,111 | 2,160 | 2,730 | 1,600 | [illegible] | [illegible] |
| Fe | 14,200 | 35,100 | 123,500 | 16,000 | 24,000 | 17,000 | 46,500 | 92,000 | 17,100 | 12,933 | 58,000 | [illegible] | [illegible] |
| Co | | | | 70 | 100 | | <24 | 13 | 41 | 35 | 19 | [illegible] | 11 |
| Ni | <300 | <300 | <190 | 210 | 1,090 | | <200 | 67 | 100 | 85 | <110 | <250 | <70 |
| Cu | 900 | 2,270 | 1,200 | 450 | 510 | 1,400 | 550 | 304 | 415 | 375 | 2,009 | 650 | 1,700 |
| Zn | 5,000 | 2,000 | 3,000 | 5,500 | 10,000 | 2,300 | | 4,733 | 32,400 | 27,967 | | | |
| As* | | | | | | | <1,200 | 7 | 154 | 168 | 623 | <1,270 | <350 |
| Se* | | | | | | | <700 | 0 | 10 | 0 | <430 | <350 | 350 |
| Ag* | 200 | <100 | <120 | 30 | 130 | | <33 | 0 | 0 | 0 | <17 | [illegible] | <14 |
| Cd* | | | | 41 | 64 | | <17 | 24 | 683 | 530 | 8.9 | [illegible] | [illegible] |
| In | | | | | | | | | | | | | |
| Sn | 600 | 700 | 800 | 400 | 1,250 | 110 | | 314 | 834 | 590 | | | |
| Sb | | | | 120 | 340 | | <255 | | | | <140 | <250 | <120 |
| La | | | | | | | | | | | | | |
| Ce | | | | | | | | | | | | | |
| Sm | | | | | | | | | | | | | |
| Eu | | | | | | | | | | | | | |
| Lu | | | | | | | | | | | | | |
| Yb | | | | | | | | | | | | | |
| Th | | | | | | | | | | | | | |
| Hf | | | | | | | | | | | | | |
| Ta | <300 | <300 | 2,000 | | | | | | | | | | |
| W | | | | | | | | | | | | | |
| Au | | | | | | | | | | | | | |
| Pb* | 4,000 | 5,000 | 5,000 | 1,730 | 7,200 | 310 | <470 | 2,633 | 8,533 | 8,033 | 250 | [illegible] | [illegible] |
| Be* | | | | | | | <2.4 | 0 | 0 | 0 | 1.3 | [illegible] | 1 |
| Hg* | <300 | <500 | <300 | 0.4 | 0.9 | | | 0 | 5 | 5 | | | |
| F | 12,800 | 7,800 | 8,400 | 6,900 | 12,200 | | 13,500 | 13,133 | 58,167 | 51,333 | 5,800 | [illegible] | 5,500 |
| Li | | | | 19 | 34 | | | | | | | | |
| Si | 171,100 | 141,100 | 188,300 | | | | 86,700 | 1,333 | 1,783 | 2,133 | 81,000 | [illegible] | [illegible] |
| P | 5,100 | 8,500 | 10,300 | | | | 5,000 | 5,467 | 4,600 | 5,500 | 2,500 | 3,600 | 230 |
| C | 14,800 | 185,700 | 14,400 | | | | | | | | | | |
| S | 9,000 | 3,600 | 1,800 | | | | | | | | | | |
| Ca | 100 | <100 | <200 | | | | | | | | | | |
| Mo | <100 | <100 | <100 | | | | 590 | 29 | 56 | 64 | 170 | 200 | 240 |
| Er | 200 | <100 | 100 | | | | | | | | | | |
| Bi | | | | | | | | 0 | 36 | 17 | | | |
| B | | | | | | | | 85 | 150 | 292 | | | |

*Appear to be some results.
[b]Converted from percent by weight.
[c]EP Toxicity Test Element.

Source: GCA Corp., 1986

# TABLE 4-4

## MWC SOLID RESIDUE ORGANIC COMPOSITION (UNITS IN ppb)

| Compound | Mass Burn Incinerator, N.H. [6] | | Chicago, N.S. Incinerator [9] | Philadelphia Incinerator [10][a] | | Shaw [11][b] | | Prince Edward Island Incinerator [6][c] | | | Fly Ash Averages [12] | | Environment Canada Fly Ash Study [20] | EPA Studies |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fly Ash | Bottom Ash | Combined Ash | Fly Ash | Bottom Ash | ESP Ash | Bottom Ash | Bottom Ash | Boiler Ash | Economizer Ash | Canada | N. America | | |
| 1,2-Dichlorobenzene | 860 | 6.32 | | 1,600 | 110 | 23 | 0.5 | 0 | 78 | 31 | 28.3-194 | 29.5-864 | | |
| 1,3,5-Trichlorobenzene | 2.3 | | | 42 | 0.7 | | | | | | | | 42[d] | 1 |
| 1,2,4-Trichlorobenzene | 2,050 | 9.3 | | 1,190 | 61 | 46 | 0.6 | 0 | 11 | 13 | | 54.1-2,96- | | |
| Hexachlorobenzene | <1 | 1.9 | | | | 3.6 | 0.4 | 4 | 4 | 0 | | | | 3.,0ec |
| Naphthalene | 9,300 | 570 | | | | | | 66- | 27- | 69 | | | | |
| Acenaphthylene | 3,560 | 390 | | | | | | 37 | 0 | 5 | | | | |
| Fluorene | 36 | <80(<800) | | | | | | 150 | 6 | 1 | | | | |
| Phenanthrene | 7,600 | 540 | | | | | | 540 | 21 | 31 | | | | |
| Dibutyl phthalate | 420(<3060) | 463 | 23 | | | | | | | | | | | |
| Fluoranthene | 8,540 | 233 | 13 | | | | | 110 | 3 | 19 | | | | |
| Pyrene | 5,490 | 220 | 10 | | | | | 150 | 3 | 8 | | | | |
| Butyl benzyl phthalate | 600(<700) | 191 | | | | | | | | | | | | |
| Chrysene | 693 | 131 (640) | | | | | | 37 | 0 | 3 | | | | |
| Bis(2-ethylhexyl) phthalate | 81 | 2,100 | 330 | | | | | | | | | | | |
| Benzo(b)fluoranthene | 490 | 80(<552) | | | | | | | | | | | | |
| Benzo(k)fluoranthene | 220 | 204(<1151) | | | | | | 31 | 0 | 0 | | | | |
| Benzo(a)pyrene | 190 | 62(<360) | | | | | | 9 | 0 | 3 | | | | |
| Anthracene | | | | | | | | 53 | 1 | 4 | | | | |
| Acenaphthene | | | | | | | | 28 | 0 | 0 | | | | |
| Dibutylphthalate | | | | | | 6.8 | 0.3 | 17 | 220 | 0- | | | | |
| Chlorophenols | | | | | | 43 | 3.0 | 0 | 520 | 7 | | | | |
| Benzo(a)fluorene | | | | | | | | 99 | 5 | 0 | | | | |
| Indeno pyrene | | | | | | | | 3 | 0 | 0 | | | | |
| Dibenzo(a,h)anthracene | | | | | | | | 4 | 0 | 3 | | | | |

[a]Values are averages for tests at four incinerators
[b]Solid waste retention unit. Values are averages for 13 runs.
[c]Values are averages for runs 2-6, normal operating conditions.
[d]Separate from electrostatic ash.
<0.5 - Below detection.
ND - Not detected

[e]Variability in observed levels of dioxin emissions could be attributable to one or more factors including lab quality control, sampling and analysis methods, and waste feeds and operating conditions at different

Source: GCA Corp., 1986

TABLE A-5

MWC RESIDUE MONOFILL LEACHATE CHEMICAL ANALYSIS (All Units mg/l)

| Parameter | Vestskoven, Germany [21] | Grobmehring, Germany [21] | Lacy St., CA [21] | Saugus, MA [21] | Auburn, ME [22] | Philadelphia, PA [23] | Primary drinking water standards | Secondary drinking water standards |
|---|---|---|---|---|---|---|---|---|
| COD | 36 | | | | 456.7 | 1,265 | | |
| TSS | | | | | 5,730.7 | | | 500 |
| TDS | | 28,900 | 11,300 | | | 7,933 | | |
| Alkalinity | | | 43 | | | 4,260 | | |
| Cl | | 18,500 | 1,700 | | 7,500 | 1,803 | | |
| Na | | 4,000 | 200 | | | 3,350 | | |
| Pb* | .012 | .25 | | .06 | .033 | 1.16 | .05 | |
| Cd* | BDL | BDL | | .01 | .003 | | .010 | |
| Cu | 24 | | 1 | .05 | .022 | 1.15 | | 1 |
| Ni | BDL | BDL | | .05 | | | | |
| Zn | .025 | BDL | | .39 | .047 | .95 | | 5 |
| pH | | | | | 8.04 | 8.3 | | |
| Mn | | | | | | | | .05 |
| Fe | | | | | .168 | 4.95 | | .3 |
| Cr* | | | | | .006 | 1.53 | .05 | |
| As* | | | | | | | .05 | |
| Ba* | | | 1 | | | | 1 | |
| Hg* | | | | | | | .002 | |
| N (as nitrate) | | | | | | 3.52 | 10 | |
| Se* | | | | | | | .01 | |
| Ag* | .040 | | | | | | .05 | |
| Endrin* | | | | | | | .0002 | |
| Lindane* | | | | | | | .004 | |
| Methoxychlor* | | | | | | | .1 | |
| Toxaphene* | | | | | | | .005 | |
| 2,4-D* | | | | | | | .1 | |
| 2,4,5-TP Silvex* | | | | | | | .01 | |
| Chloride | | | | | | | | 250 |
| Sulfate | | | | | | | | 250 |

*EP Toxicity Test Compound

COD - Chemical Oxygen Demand

TSS - Total Suspended Solids

TDS - Total Dissolved Solids

BDL - Below Detectable Limits

= - Exceed Standard

Source: GCA Corp., 1986

TABLE 4-6

EP TOXICITY RESULTS ON MWC RESIDUES (Units in mg/l)

| Contaminant | Site 1[a] (24) | Site 2[b] (24) | | Site 2 Recum[b] (24) | | Site 3[c] (24) | | Site 4[d] (24) | | | Site 4 Recum[d] (24) | | Site 5[e] (24) | Site 6[f] (24) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Combined Ash | Fly Ash | Bottom Ash | Fly Ash | Bottom Ash | Fly Ash | Bottom Ash | Fine Fly Ash | Coarse Fly Ash | Composite Ash | Fly Ash | Composite Ash | Residue | Fly Ash | Bottom Ash | [illegible] |
| As | <.0025 | <.0025 | <.0025 | <.008 | <.008 | <.0025 | <.0025 | <.0025 | <.0025 | <.0025 | <.008 | <.008 | <.0025 | <.008 | <.008 | <5.0 |
| Ba | .186 | .126 | .131 | .565 | .460 | .092 | .298 | .091 | .067 | .184 | .490 | .510 | .488 | .690 | .310 | 34. |
| Cd | .056 | 2.442 | .018 | 2.720 | .041 | .097 | .018 | 8.560 | 17.408 | .251 | 10.880 | .165 | .020 | 17.110 | .93 | 1.0 |
| Cr | .006 | .006 | .038 | .053 | <.02 | .016 | .027 | .012 | .019 | .039 | <.02 | <.02 | .032 | .135 | <.020 | 5.0 |
| Pb | .117 | 12.20 | .203 | 3.145 | .420 | .019 | .160 | 12.50 | 47.10 | .337 | 12.455 | 2.245 | .870 | 53.350 | .590 | 5.0 |
| Hg | <.0001 | .0007 | <.0001 | <.0002 | <.0002 | .0001 | <.0001 | .0009 | .0008 | <.0001 | .0013 | <.0002 | .0065 | .0004 | .0003 | 0.2 |
| Se | <.0025 | .010 | <.0025 | .048 | <.010 | <.0025 | <.0025 | <.0025 | <.0025 | <.0025 | .052 | <.010 | .0025 | .085 | <.010 | 1.0 |
| Ag | <.001 | .005 | <.001 | .035 | .015 | <.001 | <.001 | <.007 | <.008 | <.001 | <.010 | <.015 | <.001 | <.045 | <.010 | 5.0 |
| Endrin | <.003 | <.003 | <.003 | <.003 | <.003 | <.003 | <.003 | <.003 | <.003 | <.003 | <.003 | <.003 | <.003 | <.003 | <.003 | .02 |
| Lindane | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | 0.4 |
| Methoxy-chlor | <.005 | <.005 | <.005 | <.005 | <.005 | <.005 | <.005 | <.005 | <.005 | <.005 | <.005 | <.005 | .005 | <.005 | <.005 | 10 |
| Toxaphene | <.005 | <.005 | <.005 | <.005 | <.005 | <.005 | <.005 | <.005 | <.005 | <.005 | <.005 | <.005 | .005 | <.005 | <.005 | 0.5 |
| 2,4-D | <.04 | <.04 | <.04 | <.001 | <.001 | <.04 | <.096 | <.04 | <.04 | <.04 | <.001 | <.001 | .04 | <.001 | <.001 | 10. |
| 2,4,5-TP Silvex | <.01 | <.01 | <.01 | <.001 | <.001 | <.01 | <.01 | <.01 | <.01 | <.01 | <.001 | <.001 | <.01 | <.001 | <.001 | 1.0 |

[a] Mass burn MSW in two rotary kilns. Bottom ash is water quenched. Fly ash is captured by low energy, packed bed scrubber and then mixed in quench trou[illegible] No heat recovery. Ferrous metal is removed from residue.

[b] Burns MSW, commercial waste, and selected industrial waste. Plant consists of coarse shredders, air classifier, spreader stoker-fired waterwall boiler[illegible] Produces steam.

[c] Burns MSW. Plant consists of bag breaker (flail mill), rotary screen, shredder, ferrous separation, and air classifier. Bottom ash is collected in dr[illegible] ash pit, fly ash is collected by electrostatic precipitators.

[d] Mass burns MSW. No front-end recovery. Fe metal is removed from ash, which is water quenched, and combined with fly ash from Electrostatic Precipitator. Produces Steam.

[e] Multiple chamber burning of Raw MSW. Some removal of large metals at front end. No other salvage. No fly ash collection. Produces steam.

[f] Mass burns MSW, in 5 incinerator units with forced air fixed grate. Bottom ash is water quenched and fly ash is captured by Electrostatic Precipitator.

— = Exceed standard.

# TABLE 4-6

## Continued

| Element | Avon, IN [24] | | No port, FL [24] | | Saugus, MA [21] | | | Chicago, IL [21] | | | Mont. Co., OH [24] | | | Salem, VA [13] | Rockville, IN [21] | Resource Recovery Ash [7] | | | | Max Conc. Allowed |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bottom Ash | Fly Ash | Bottom Ash | Fly Ash | Bottom Ash[a] | Fly Ash | Combined Ash[b] | Boiler Ash | Fly Ash | Combined Ash | Combined Ash | Combined Drained | Combined Weathered | Combined Ash | Combined Ash | Chicago, IL | Sumner, TX | Hampton, VA | Auburn, NE | |
| As | BDL | BDL | .022 | .050 | | | | BDL | BDL | .0029 | BDL | BDL | BDL | BDL | .004 | .003 | .009 | .017 | .002 | 5.0 |
| Ba | 176 | 126 | 1.0 | 775 | | 92.9 | | 091 | .069 | .186 | .46 | 325 | .146 | .<98 | 2.0 | | | | | 100. |
| Cd | .018 | 7.44 | .135 | 2.35 | .58 | | 3.94 | 8.56 | 17.4 | .251 | .425 | .141 | .056 | .020 | BDL | .210 | .340 | .500 | .030 | 1.0 |
| Cr | .038 | .066 | ND | .059 | | | | .012 | .019 | .039 | .016 | .011 | .006 | .012 | BDL | .030 | .042 | .033 | .011 | 5.0 |
| Pb | 283 | 12.7 | 4.17 | 8.195 | 9.19 | 29.8 | 30.43 | 12.5 | 67.3 | .337 | 1.54 | 1.30 | .117 | .070 | .7 | 5.8 | 6.4 | 10.3 | 3.85 | 5.0 |
| Hg | BDL | .0007 | .025 | .0016 | | | | .0004 | .0008 | BDL | BDL | BDL | BDL | .0065 | BDL | | | | | 0.2 |
| Se | BDL | .018 | .020 | .018 | | | | BDL | BDL | BDL | BDL | BDL | BDL | BDL | .004 | .003 | .002 | .002 | .002 | 1.0 |
| Ag | .001 | .005 | .085 | .185 | | | | .007 | .008 | BDL | BDL | BDL | BDL | BDL | BDL | | | | | 5.0 |
| Fluoride | | | | | | | | | | | | | | | | | | | | .02 |
| Endrin | | | | | | | | | | | | | | | | | | | | 0.4 |
| Methoxychlor | | | | | | | | | | | | | | | | | | | | 10. |
| Toxaphene | | | | | | | | | | | | | | | | | | | | 0.5 |
| 2,4-D | | | | | | | | | | | | | | | | | | | | 10. |
| 2,4,5-TP Silvex | | | | | | | | | | | | | | | | | | | | 1.0 |

BDL - Below Detectable Limits

ND - No determination

[a]Average of 2 sets of data

[b]Average of 3 sets of data

Note: No plant descriptions documented except Chicago R.R. (see Table 1 notes).

Source: GCA Corp., 1986

## 5.0 CONCLUSIONS

Municipal solid waste landfill leachate production volume and leachate chemical composition are dependent on many variables; some of which are related to climatology, geography, geology, and hydrology and others of which are related to landfill engineering design and operating procedures. Thus, some variables are uncontrollable because they are inherent to the location and can only be controlled via a proper site selection process; others are controllable. The controllable and noncontrollable variables include the following:

- Availability of water
- Surface conditions
- Refuse composition, condition, and depth
- Underlying soil conditions
- Landfill age or degree of stabilization

The hazardous small-quantity-generator exclusion rule under RCRA has allowed the disposal of small quantities of hazardous materials in municipal landfills. Codisposal of industrial wastes can cause leachates to contain elevated levels of toxic inorganic and organic materials. Some of these contaminants, particularly the metals, can inhibit the biological activity needed to decompose the solid wastes. Thus they can interfere with the natural stabilization phases of the landfill and create a more concentrated, contaminant-carrying leachate. At the same time, organic solvents may increase the solubility of organics present in the solid waste and thus also increase the contaminant loading of the leachate.

Codisposal of municipal waste combustion ashes with other municipal wastes is practiced in the United States. These ashes have been shown to contain dioxins and chlorinated dibenzofurans and to leach elevated levels of metals under both codisposal and monofill conditions.

Selective and careful sampling of leachates generated from newer solid waste disposal sites and analyses of these leachates for both hazardous organic and inorganic constituents (RCRA, Appendix IX) may provide important information regarding the chemical composition of these leachates. Such information could

serve as a data base to be used for making decisions concerning changes to the Subtitle D Program.

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